An AUV-Based Investigation of the Role of Nutrient Variability in the Predictive Modeling of Physical Processes in the Littoral Ocean

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LONG-TERM GOALS

Our long-term goal is to explore and test the potential effectiveness of low-level nutrient concentrations (nitrate, nitrite, and ammonia) as descriptors of geophysical fields and tracers of physical processes in oligotrophic coastal waters, with particular attention to adapting our laboratory sensor for these nutrients for use in an AUV. The nutrient data are to be incorporated into prognostic physical-biogeochemical models in a feedback mode.

OBJECTIVES

The first objective was to modify the AUV nutrient sensor to improve detection limits and reliability. We expected important progress toward a final version that will have detection limits acceptably close to those of our high-sensitivity laboratory version: ~5 nanomolar (Masserini and Fanning, 2000a).

The second objective was to compare nutrient distributions in the field obtained by the laboratory and AUV versions of the nutrient sensor package. The comparison would be conducted on the West Florida Shelf in the area designated as the ECOHAB Control Volume in order to relate the results to our regular nutrient surveys in the region and to physical circulation measurements made by USF current-meter moorings.

The third objective was to perform high-sensitivity nutrient surveys with the laboratory version of our nutrient sensor package at the same time and in the same waters as surveys of sulfur hexafluoride (SF_6),

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which would be injected at a site in the Control Volume near one of the moorings in the center of the USF array. Out of this work was expected to come comparisons of concurrent distributions and spatio/temporal trends of nutrients and SF_6. Ultimately, dispersion coefficients determined using surficial changes in nutrient concentrations might be compared to those obtained from SF_6 concentration changes.

The fourth objective was to investigate the effects of turbulence and stratification in different seasons on the nutrient/ SF_6 comparisons.

The fifth objective was to begin to apply coupled LES biophysical-based modeling to the measured distributions of nutrients, SF_6, and temperature and salinity.

APPROACH

Objective 1:
To improve the detection limits of the AUV version of the nutrient sensor and make it operate reliably, upgrades were needed in electronics, mechanical components, software, and the heaters that speed up the nutrient-reagent reactions. The signal-to-noise ratio, a major factor affecting the sensitivity of the AUV package, had to be increased. Key individuals were R. Masserini and K. Fanning of the College of Marine Science and D. Russell, S. Sampson, and J. Patten of the Center for Ocean Technology.

Objectives 2 and 3:
Two 15-day cruises on the R/V Pelican provided (or will provide) a superb opportunity for SF_6/nutrient comparisons. These cruises were so vital to the SF_6 work of R. Wanninkhof at AOML that NOAA paid for the shiptime on the first one (FSLE 3 in July 2000) and will also pay for the second one (FSLE 4 in Nov. 2000). The approach for the first one was simultaneous measurement of nutrient and SF_6 concentrations on a stream of seawater flowing from the sea chest(s) of the vessel about 3 meters below sea level. These measurements commenced after an injection of SF_6. Other measurements made on the same stream were temperature, salinity, and CDOM fluorescence. Once a day, the AUV version of the sensor was deployed by a team from Ocean Engineering group of FAU led by J. Jalbert. This team was responsible for the propulsion section and the control and positioning of the AUV track. A hydrocast and an optical cast to the bottom were taken once a day. Overflights of aircraft with optical sensors were also regularly taken. The CDOM work (P. Coble of USF), the optical casts (K. Carder of USF), and the overflights (P. Bissett of the Florida Environmental Research Institute) are associated with the ONR HyCODE project. R. Weisberg of USF directs the operation of the moorings that provide the vital background current and physical data.

Objective 4:
Cruises were planned in different seasons in order to determine the effects of variations in stratification on the nutrient/SF_6 comparisons. The July Pelican cruise was the summer (high stratification) cruise. The upcoming Nov. Pelican cruise will compare nutrients and SF_6 in a lower-stratification regime. Stratification effects were to be assessed, in part, by comparing changes in the agreement between nutrient and SF_6 dispersion coefficients. Turbulence effects on the nutrient/SF_6 comparison work were to be studied by conducting LES/biochemical modeling of the distributions and considering the effect of

various mixing coefficients on the agreement between the dispersion of nutrient and SF_6 signatures of surficial water masses. Involved in this work are K. Fanning, R. Masserini, and J. Walsh of USF; R. Wanninkhof of NOAA, and R. Garwood of the Naval Postgraduate School (NPS).

Objective 5:
The approach to this objective is to conduct iterative modeling exercises using biophysical, POM-based, LES models of nutrient and SF_6 distributions (Harcourt et al., 1997). Key individuals are R. Garwood, J. Walsh, and R. Weisberg with input from K. Fanning and R. Wanninkhof.

WORK COMPLETED

Objective 1:

A major problem was that the chemical heaters on the AUV version of the nutrient sensor worked very badly, sometimes even clogging. The fix was to design and build pressure-compensated electrical heaters. Pump control, pump speed, the pump gearbox, and thus timing of reagent delivery were also greatly improved. Installation of a valve, better microcontrollers, and upgraded software permitted automatic standardization. Modifications to the controlling software improved the GUI interface and the integration of propulsion-section data. Problems with microporous tubing (e.g., a failure under pressure cycling) and valve components (corrosion in seawater) were fixed. A problem with the reliability of the AUV pressure sensor was identified.

Objectives 2 and 3:
Results relevant to both objectives were obtained on cruise FSLE-3. After some equipment testing, SF_6 was injected 10 m deep at the NAVY 3 mooring (27.156° N, 82.932° W). For a few days, surveys of nutrients with the laboratory sensor were conducted; then simultaneous surveys of nutrients and SF_6 commenced round the clock for 4 days as we followed the spreading SF_6 patch. In 10 days, a total of 38, two-hour, laboratory-version nutrient surveys were run. AUV surveys were conducted once a day; the vessel steamed along a track at 3 knots with simultaneous laboratory-sensor nutrient measurements as the ship steamed on an adjacent, nearly parallel track offset 10-100 meters, depending on wind drift, currents, ship speed, etc.

Objectives 4 and 5:
Raw data required for these objectives were obtained in July on FSLE 3. Data processing is underway. A conference between investigators from USF (Fanning, Walsh, Weisberg, Coble), NOAA (Wanninkhof) and the Naval Postgraduate School (Garwood) was held on 9/13/00 to consider initial results for processed data. Data were exchanged, and plans for evaluation were discussed, including using variability in nighttime temperature to assess turbulence and to predict nighttime variability in nutrients and SF_6.

RESULTS

Objective 1:

Detection limits decreased from > 500 nanomolar (nM) to 150 nM (nitrate), 75 nM (ammonia) and 50 nM (nitrite) – still too high, but much closer to desired goal of 5-10 nM. The AUV nutrient sensor itself is now robust and reliable, when properly deployed and propelled. On FSLE 3 in July, eight deployments were tried. Four failed because of problems with FAU's equipment. Then, after their equipment was fixed and a software adjustment to use the FAU pressure sensor as a control over the start/stop sequencing was made, we had 4 successful deployments in a row – one each day.

Objectives 2 and 3:

Fig. 1 shows comparisons between AUV results and laboratory sensor results on Survey 36 near the end of FSLE 3. While it is tempting to consider the differences between the red and blue lines a measure of horizontal nutrient variations over distances of 10-100 m, reality requires that the high detections limits of the AUV version be applied (75 nM for NH_3 and 50 nM for NO_2) with the result that the red and blue lines are statistically indistinguishable in both graphs. After the expected future improvement in detection limits in the AUV version, graphs like Fig. 1 would indeed show fine scale nutrient variations in surface waters

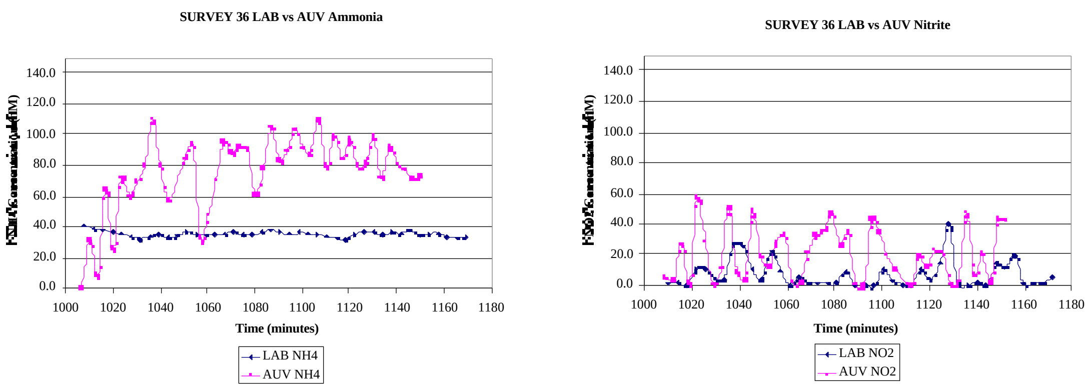

Fig. 1. Simultaneous nutrient data surveys by Laboratory sensor and AUV sensor

Fig. 2 shows the simultaneous variations in nutrients (via Laboratory sensor) and SF_6 along Nutrient Survey 19 taken 5 days after the SF_6 injection and Nutrient Survey 37 taken 8 days after the injection. Survey 19 shows a passage through an SF_6 maximum, which is part of the spreading bolus of SF_6-labelled water. At the same time, it shows various local nutrient maxima (mainly ammonia and nitrate) plus a broader increase in ammonia and nitrate toward the end of the survey where SF_6 decreases indicate that we were on the other side of the bolus. The fine-scale nutrient structure visible prompts

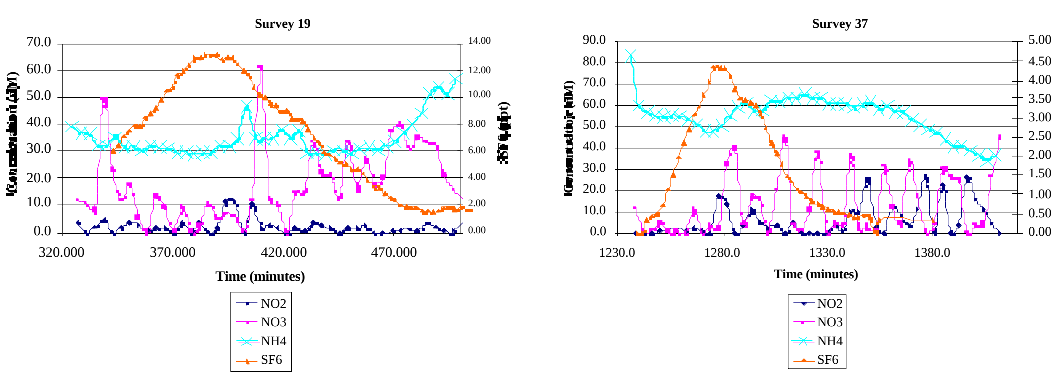

Fig. 2. Simultaneous data on SF_6 and nutrients (Laboratory Sensor) around the SF_6 bolus

some interesting questions. For example, can the local ammonia maximum within the SF_6 peak at ~400 min be identified on other surveys, and did it shrink and spread in a way that is predictable by the shrinkage and spreading of the SF_6 peak? Also, was the the low SF_6/high ammonia region after 440 min encountered again? How had it changed, and are the ammonia changes predictable from the SF_6 changes?   Survey 37 also shows a low SF_6/high ammonia region, this time at the beginning of the survey. Are the two regions the same? What happens to the ammonia minimum under the SF_6 peak?

Objectives 4 and 5:
No results yet.

IMPACT/APPLICATIONS

Nutrient concentration distributions obtained by both the laboratory version and the AUV-version of our nutrient sensor package can reveal differences in surface water types that will be useful for applying a non-hydrostatic LES model to compute small scale flows within the POM grid cells. At the turbulence integral scale, physical processes accomplish most of the vertical mixing and dispersion of nutrients (and plankton), and the LES model solutions can be brought to statistical quasi-steady state for a variety of conditions in the Ro, Ri parameter space. This will have applications to SF_6 studies, to prediction of red-tide distributions, and to estimates of tempo-spatial variance of IOP.

TRANSITIONS

Once the models replicate these observations of small-scale features of physico-chemical processes on the West Florida shelf, we would anticipate applying them to other ongoing ONR field studies: COBOP at Lee Stocking Island in the Bahamas and LEO-16 on the New Jersey shelf.

RELATED PROJECTS

J. Walsh (N000149910212) is developing a model of plankton succession effecting bio-optical signals on the West Florida shelf. Forty-years of shelf nutrient, plankton, and physical data will be used along with our data to validate the model, based on existing circulation and nutrient-cycling models.

R. Weisberg of USF (N000149810158) is applying a primitive equation model at 5-km resolution to observed West-Florida-shelf current fields. It is an adaptation of the POM with topography-following vertical sigma coordinates and horizontal orthogonal curvilinear coordinates. Far-field shelf-break forcing is also being examined. It will provide boundary values for the LES modeling of nutrient/SF_6 data, and the resulting nowcasts and forecasts can be calibrated by our measured distributions.

P. Bissett of FERI (N000149810844) is applying Ecological Simulation 2.0 [EcoSim 2.0] to the West Florida shelf to model daily changes in the spectral quality of the downwelling light field. Daily IOP outputs are also coupled with the Hydrolight 4.0 radiative transfer code to predict the upwelling light field at 10:00 am each day. POM, LES, EcoSim 2.0, and the microalgal succession submodel described above will form a 3-D, ecologically complex, bio-optical shelf model (requiring our nutrient data).

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